SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Takashi Kamada, a
citizen of Japan residing at Kawasaki, Japan, Motoyoshi
Sekiya, a citizen of Japan residing at Kawasaki, Japan and
Ryosuke Goto, a citizen of Japan residing at Kawasaki,
Japan have invented certain new and useful improvements in

LOSS POINT DETECTING METHOD AND DISTRIBUTED
RAMAN AMPLIFIER APPLYING THE SAME

Of which the following is a specification:-

<u>TITLE OF THE INVENTION</u>

LOSS POINT DETECTING METHOD AND
DISTRIBUTED RAMAN AMPLIFIER APPLYING THE SAME

5 <u>BACKGROUND OF THE INVENTION</u>

1. Field of the Invention

The present invention relates to a loss
point detecting method and a distributed Raman
amplifier applying the same, and, in particular, to

10 a loss point detecting method used in an optical
system and a distributed Raman amplifier applying
the same.

2. Description of the Related Art

15 Recently, a demand for communications
rapidly increases in many countries along with a
sharp spreading of the Internet or a development of
multimedia society. For the purpose of catching up
therewith, introduction of a backbone optical

20 transmission system applying a WDM (wavelength
division multiplexer) technology has been proceeded
with, whereby increase in the transmission capacity
is directed to.

In order to increase the transmission

25 capacity, various methods such as time-division
multiplexing, wavelength division multiplexing and
so forth are considered, and, in particular, the
method of wavelength division multiplexing is
expected as being applied for the purpose of further

30 increasing the transmission capacity with a seek for
wider-band wavelength and a study concerning
wavelength separation. However, in case of applying
the technology for a use of long-distance
transmission, an optical signal is attenuated there,

35 and, thus, repeating or amplifying thereof is needed
on the way.

There are two types of methods for

amplifying an optical signal in an optical
transmission path, i.e., of a stimulated emission
type and of a Raman scattering type, and a
distributed Raman amplifier (DRA) which applies the
5   Raman scattering type amplification has been taken
into a practical use widely in that it is possible
to freely select the amplifying wavelength.

A WDM optical transmission system has a
transmission station which generates a wavelength-
10   multiplexed signal light, an optical transmission
path transmitting the signal light generated by the
transmission station, and a reception station which
receives the signal light thus transmitted. Further,
as needed, repeaters amplifying the signal light may
15   be provided in the optical transmission path.

FIG. 1 illustrates a distributed Raman
amplifier in the related art used in such a WDM
optical transmission system (see Japanese laid-open
patent application No. 2000-314902, for example).
20   In the configuration shown, a signal light having
the wavelength of 1.55 μm, for example, is
transmitted through an optical fiber 10. This
signal light is applied to a band separation optical
coupler 12. Also, to the band separation optical
25   coupler 12, an excitation light with the wavelength
of 1.45 μm is supplied from an excitation light
source 14 via an optical coupler 16. The signal
light amplified optically with the supply of the
excitation light is then sent out to a subsequent
30   optical fiber via an optical coupler 18.

In the optical coupler 16, the excitation
light from the excitation light source 14 is
separated, and the power of the excitation light is
monitored by an excitation light monitor 20, and the
35   thus-obtained monitoring signal of the power of the
excitation light is supplied to a control circuit 22.
The signal light separated by the optical coupler 18

is monitored by a signal light monitor 24, and the thus-obtained monitoring signal of the power of the signal light is supplied to the control circuit 22. The control circuit 22 adjusts the excitation light power which the excitation light source 14 originally outputs according to the thus-obtained respective monitoring signals of the excitation light power and signal light power.

The distributed Raman amplifier (DRA) can perform amplification in an arbitrary wavelength zone, by appropriately setting the wavelength of the excitation light, and also, is advantageous in that the optical amplifying medium can be used also as the optical transmission path. Assuming that 'go' denotes the Raman gain factor, Pi denotes the applied excitation light power, Aeff denotes the nonlinear effective cross-sectional area, and Le denotes the DRA effective length, generally, the DRA gain Gr is expressed by the following formula (1), and the DRA effective length Le is expressed by the following formula (2);

Gr = exp[(goPiLe)/(2Aeff)]   ...(1)

$$Le = \int_0^L P(z) \diagup Pidz \qquad \cdots (2)$$

There,

P(z) = Pi $\cdot$ exp[-α(L-z)]

There, α denotes a constant, and 'z' denotes a relevant position along the optical fiber 10 assuming that L denotes the position of the band separation optical coupler 12.

SUMMARY OF THE INVENTION

An optical loss occurs due to some cause such as a junction of the optical fiber 10 performed in a poor manner or so. A point at which such an optical loss occurs is referred to as a loss point,

5   hereinafter. When such a loss point occurs near the DRA (distributed Raman amplifier), the gain Gr of the DRA becomes greatly lowered as can be seen from the above-mentioned formulas (1) and (2).

FIG. 2 shows a calculation result of the

10   above-mentioned DRA gain Gr assuming that the Raman gain factor 'go' is 6.7×10^{-14} [m/W], the applied excitation light power Pi is 1.6 [W], the nonlinear effective cross-sectional area Aeff is 102 [μm^2], the length of the optical fiber transmission path is

15   100 [km], and the loss occurring at the loss point is 0 [dB], 1 [dB], 2 [dB], and 3 [dB].

The applied excitation power is controlled according to the monitoring result of the signal light power. Accordingly, when the DRA gain is

20   small due to the existence of the loss point, the applied excitation light power is increased automatically as large as possible up to the maximum value of the excitation light power in some case in order to obtain a necessary signal light power as

25   shown in FIG. 3. At the loss point, a rate at which the energy of light is transformed into thermal energy is large compared with another point in the optical fiber 10. Accordingly, when the excitation light reaches the loss point while the optical

30   energy thereof is high, burning out of the fiber material may occur there accordingly.

According to the distributed Raman amplifier in the related art, as shown in FIG. 1, the amplified signal is separated by the optical

35   coupler 18, the light power is monitored after that, and, therewith, the excitation power adjustment control is performed. However, in case the loss

point occurs in the optical transmission path, a sufficient gain may not be obtained even when the excitation light power is increased accordingly.

Therefore, as shown in FIG. 3, the
5 excitation light power is increased for obtaining a necessary signal light power, and, as a result, the optical transmission path material may be burned out at the loss point as mentioned above in a worse case.

The present invention has been devised for
10 the purpose of solving this problem, and, an object of the present invention is to provide a loss point detecting method for determining whether any loss point occurs for the purpose of avoiding a problematic situation such as a burning out of the
15 optical transmission path material as mentioned above, and a distributed Raman amplifier which applies this method.

According to a first aspect of the present invention, a scattered light separated from the
20 optical transmission path is monitored, a part of the excitation light is separated and is monitored, a reflected light which passes in a direction opposite to the direction in which the signal light passes through the optical transmission path is
25 monitored, and, when the power of the excitation light monitored reaches a predetermined determination value, it is determined whether or not any loss point occurs based on a ratio between the power of the scattered light monitored and the power
30 of the reflected light monitored.

According to a second aspect of the present invention, the scattered light separated from the optical transmission path is monitored, a part of the excitation light is separated and is
35 monitored, and, when the power of the excitation light monitored reaches a predetermined determination value, it is determined whether or not

any loss point occurs based on the power of the scattered light monitored.

According to a third aspect of the present invention, a scattered-light monitoring part monitoring a scattered light separating from the optical transmission path; an excitation-light monitoring part separating a part of the excitation light and monitoring it; a reflected-light monitoring part separating a reflected light which passes in a direction opposite to the direction in which the signal light passes through the optical transmission path, and monitoring it; a determining part determining, when the power of the excitation light monitored reaches a predetermined determination value, whether or not any loss point occurs based on a ratio between the power of the scattered light monitored and the power of the reflected light monitored; and a breaking part breaking the excitation light when the determining part determines that a loss point occurs are provided. Thereby, it is possible to avoid burning out of the optical transmission path material at the loss point if any.

According to a fourth aspect of the present invention, a scattered-light monitoring part monitoring a scattered light separating from the optical transmission path; an excitation-light monitoring part separating a part of the excitation light and monitoring it; a reflected-light monitoring part separating a reflected light which passes in a direction opposite to the direction in which the signal light passes through the optical transmission path, and monitoring it; a determining part determining whether or not any loss point occurs, by increasing the power of the excitation light at a fixed rate, and comparing a time required for the power of the scattered light monitored to

reach a fixed value with a time required for the power of the reflected light monitored to reach a fixed value; and a breaking part breaking the excitation light when said determining part
5 determines that a loss point occurs are provided. Thereby, it is possible to avoid burning out of the optical transmission path material at the loss point if any.

According to a fifth aspect of the present
10 invention, a scattered-light monitoring part monitoring a scattered light separating from the optical transmission path; an excitation-light monitoring part separating a part of the excitation light and monitoring it; a determining part
15 determining, when the power of the excitation light monitored reaches a predetermined determination value, whether or not any loss point occurs based on the power of the scattered light monitored; and a breaking part breaking the excitation light when the
20 determining part determines that a loss point occurs are provided. Thereby, it is possible to avoid burning out of the optical transmission path material at the loss point if any.

25 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a block diagram of an example of a distributed Raman amplifier in the related art;

FIG. 2 shows a calculation result of a DRA gain obtained with respect to various values in the
30 loss occurring at a loss point and various value in the position of the loss point;

FIG. 3 illustrates an excitation light feedback control scheme;

FIG. 4 illustrates wavelength spectra of a
35 signal light, a scattered light, and a reflected light;

FIG. 5 shows a block diagram of a

distributed Raman amplifier according to a first
embodiment of the present invention;

FIG. 6 illustrates a reflected light power
changing as the excitation light power is increased
at a fixed rate;

FIG. 7 illustrates a scattered light power
changing as the excitation light power is increased
at a fixed rate;

FIG. 8 illustrates a relation of the
scattered light power ASS and the reflected light
power Pm with respect to the applied excitation
light power P;

FIG. 9 illustrates respective changes of
the excitation light power P, the reflected light
power Pm, the scattered light power ASS, and the
signal light power Psg in case no loss point occurs;

FIG. 10 illustrates respective changes of
the excitation light power P, the reflected light
power Pm, the scattered light power ASS, and the
signal light power Psg in case a loss point occurs;

FIG. 11 shows a block diagram of a
distributed Raman amplifier according to a second
embodiment of the present invention;

FIG. 12 illustrates a relation of the
scattered light power ASS with respect to the
applied excitation light power P;

FIG. 13 shows a block diagram of a
distributed Raman amplifier according to a third
embodiment of the present invention; and

FIG. 14 shows a block diagram of a
distributed Raman amplifier according to a fourth
embodiment of the present invention.

PREFERRED EMBODIMENT OF THE PRESENT INVENTION

Embodiments of the present invention will
now be descried with reference to figures.

When an excitation light is applied to an

optical fiber transmission path, a scattered light
and a reflected light occur other than a signal
light thus amplified, as shown in FIG. 4. And when
a loss point occurs in the optical fiber

5 transmission path as mentioned above, the scattered
light power ASS is small while the reflected light
power Pm is large. When no loss point occurs,
contrary, the scattered light power is large while
the reflected light power is small. Accordingly, a

10 first embodiment of the present invention performs
control of the excitation light power by monitoring
the scattered light power and the reflected light
power, and then based on the thus-monitored powers.

FIG. 5 shows a block diagram of a

15 distributed Raman amplifier in the first embodiment
of the present invention. As shown, a signal light
for example with the wavelength of 1.55 μm is
transmitted through an optical fiber 30 which is an
optical transmission path. This signal light is

20 applied to a band separation optical coupler 32. An
excitation light with the wavelength of 1.45 μm is
supplied also to the band separation optical coupler
32 through an optical coupler 36 from an excitation
light source 34, and, in the band separation optical

25 coupler 32, the excitation light is applied to the
optical fiber 30 in a direction opposite to a
transmission direction of the signal light.

Thereby, the signal light is amplified
with a use of the optical fiber 30 as an amplifying

30 medium. The signal light thus optically amplified
with the supply of the excitation light is sent out
to a subsequent optical fiber via a band separation
optical coupler 38 and an optical coupler 40.

In the optical coupler 36, while the

35 excitation light supplied from the excitation light
source 34 is separated, a reflected light in a
direction opposite to that of the excitation light

obtained from the band separation optical coupler 32 is also separated. The power of the excitation light is monitored by the excitation light monitor 42, and the thus-obtained monitoring signal is

5   supplied to a control circuit 44, while the power of the reflected light is monitored by the reflected light monitor 46, and the thus-obtained monitoring signal is also supplied to the control circuit 44.

        Moreover, a scattered light separated with

10   the band separation optical coupler 38 is monitored by a scattered light monitor 48, and the thus-obtained monitoring signal of the scattered light power is supplied to the control circuit 44. The signal light separated with the optical coupler 40

15   is monitored by the signal light monitor 50, and the thus-obtained monitoring signal of the signal light power is supplied to the control circuit 44.

        The control circuit 44 adjusts the excitation light power which the excitation light

20   source 34 originally outputs, according to the thus-supplied respective monitoring signals of the excitation light power, reflected light power, scattered light power, and signal light power. Upon operation of the device, i.e., DRA, the control

25   circuit 44 raises the excitation light power at a fixed rate from 0, with monitoring the scattered light power and the reflected light power.

        At this time, the reflected light power Pm increases gradually linearly, as shown with a solid

30   line shown in FIG. 6. Moreover, the scattered light power ASS also increases gradually with a curve shape, as shown with a solid line shown in FIG. 7. A time when the reflected light power arrives at a predetermined reference point 'a' is assumed as 't1',

35   and a time at which the scattered light power arrives at a predetermined reference point 'b' is assumed as 't2'.

The above-mentioned reference points 'a'
and 'b' are determined by the following manner:
First, the greatest excitation light power with
which the optical fiber 30 of the optical

5 transmission path is not burned out even with a loss
point occurring is determined. Then, the position
and the loss amount (dB) of the loss point with
which the DRA gain can have the necessary lowest
value which system requires within the thus-

10 determined excitation power are found out. Then, in
these conditions, the scattered light power ASS and
reflected light power Pm are monitored.   The thus-
obtained values of the scattered light power ASS and
the reflected light power are determined as the

15 reference points 'b' and 'a'.

FIG. 8 shows relations of the scattered
light power ASS and the reflected light power Pm
with respect to the applied excitation light power P.
The excitation light power is raised at a fixed rate,

20 and a time when the excitation light power reaches a
determination value Pjdg is assumed as tjdg. A
dashed line shown denotes the characteristic of the
optical transmission path with a loss point, and
when the excitation light power reaches the

25 determination value Pjdg, Pm/ASS still exceeds a/b
as shown. A solid line shown denotes the
characteristic of the optical transmission path
without a loss point, and in this case, when the
excitation light power reaches Pjdg, Pm/ASS already

30 becomes lower than a/b.

The control circuit 44 determines that a
loss point occurs in case the value Pm/Ass still
exceeds the value a/b when the excitation light
power P reaches the determination value Pjdg, and

35 then, turns off the excitation light, and for
example, generates an alarm signal for a host
apparatus. On the other hand, in case the value

Pm/Ass is already lower than the value a/b when the excitation light power P reaches the determination value Pjdg, the control circuit 44 determines that no loss point occurs, and then, executes a control

5 of maintaining the excitation light power at a fixed value.

In detail, FIG. 9 shows, for a case where there is no loss point (t1 > t2), respective changes of the excitation light power P, the reflected light

10 power Pm, the scattered light power ASS, and the signal light power Psg. On the other hand, FIG. 10 shows, for a case where there is a loss point (t1 < t2), respective changes of the excitation light power P, the reflected light power Pm, the scattered

15 light power ASS, and the signal light power Psg.

In actual control scheme in the first embodiment, as shown in FIGS. 9 and 10, first, the control circuit 44 raises the excitation light power P at a fixed rate until the signal light power Psg

20 reaches a target value Pth at a necessary level.

In the case shown in FIG. 10, in which, as a loss point occurs (t1 < t2), the reflected light power Pm arrives at the reference point 'a' before the scattered light power ASS arrives at the

25 reference point 'b' while the excitation light power P is raised at the fixed rate as mentioned above. The control circuit 44 then performs control of breaking the excitation light power P, before the signal light power Psg reaches the target value Pth,

30 as determining that a loss point occurs in the optical transmission path and thus burning out might occur if the excitation light power were raised more.

On the other hand, in case where there is no loss point or it can be ignored even a loss point

35 occurs (t1 > t2), the scattered light power ASS arrives at the reference point 'b' before the reflected light power Pm arrives at the reference

point 'a' as shown in FIG. 9 while the excitation
light power P is raised at the fixed rate.
Accordingly, the control circuit 44 performs a
control of raising the excitation light power P
5 until the signal light power Psg reaches the target
value Pth, and, maintaining the excitation light
power after the signal light power Psg thus reaches
the target value Pth.

Thus, by utilizing the characteristics of
10 the scattered light power and reflected light power
which change in different manners whether or not a
harmful loss point occur, it is possible to
effectively detect a harmful loss point so as to
effectively avoid actual burning out of the optical
15 transmission path material, according to the present
invention. Accordingly, at a time of starting up in
an actual field, connector joints having harmful
loss points, i.e., loss points having large losses,
are automatically detected, and, based on the thus-
20 obtained detection result, a manner of controlling
the excitation light power actually applied is
determined before the plant starts commercial
operation. Accordingly, it is possible to simplify
starting up operation and also to achieve safe
25 commercial operation.

FIG. 11 shows a block diagram of a
distributed Raman amplifier according to a second
embodiment of the present invention. In the figure,
the same reference numeral is given to the same
30 portion as that in FIG. 5. A point different from
FIG. 5. is that a band separation optical coupler 39
is provided instead of the band separation optical
coupler 38, in FIG. 11. In FIG. 11, through an
optical fiber 30 which is an optical transmission
35 path, a signal light for example with the wavelength
of 1.55 μm is transmitted. This signal light is
applied to the band separation optical coupler 32.

An excitation light with the wavelength of 1.45 μm
is supplied also to the band separation optical
coupler 32 through an optical coupler 36 from an
excitation light source 34, and, is applied, in a
5   direction opposite to the transmission direction of
the signal light, to the an optical fiber 30 with
the band separation optical coupler 32.

Thereby, the signal light is amplified by
using the optical fiber 30 as an amplifying medium.
10   The signal light thus having undergone the optical
amplification with the supply of the excitation
light is then sent out to a subsequent optical fiber
via an optical coupler 40.

In the optical coupler 36, while the
15   excitation light supplied from the excitation light
source 34 is separated, the reflected light in a
direction opposite to that of the above-mentioned
excitation light supplied from the band separation
optical coupler 32 is also separated. The power of
20   the excitation light is monitored by an excitation
light monitor 42, and the thus-obtained monitoring
signal is supplied to a control circuit 44, while
the power of the reflected light is monitored by a
reflected light monitor 46, and the thus-obtained
25   monitoring signal is supplied to the control circuit
44.

Moreover, a scattered light and the signal
light together separated with the optical coupler 40
from the optical fiber 30 are then separated into
30   the scattered light and the signal light by the band
separation optical coupler 39. Then, the power of
the scattered light is monitored by the scattered
light monitor 48, and the thus-obtained monitoring
signal of the scattered light power is also supplied
35   to the control circuit 44. Similarly, the power of
the signal light is monitored by the signal light
monitor 50, and the thus-obtained monitoring signal

of th signal light power is supplied to the control circuit 44.

The control circuit 44 adjusts the excitation light power which originally the excitation light source 34 outputs, according to the thus-obtained monitoring signals of the excitation light power, reflected light power, scattered light power, and signal light power. Operation of the control circuit 44 is the same as that in the first embodiment described above, and the duplicated description thereof is omitted.

A control manner according to a third embodiment of the present invention in which the excitation light power control is performed not monitoring the reflected light power but monitoring the scattered light power will now be described. When a loss point exists in an optical transmission path, the scattered light power ASS is small. On the other hand, the scattered light power ASS is large when there is no loss point. By utilizing this behavior, the control is made referring to a relation between the excitation light power P and the scattered light power ASS.

FIG. 12 shows a relation of the scattered light power ASS with respect to the excitation light power P in case of setting the length of the optical fiber transmission path as 100 [km] and the loss at a loss point as 1 [dB]. The five curves shown in the figure show the relations in case the loss point is located at a position of 0 [km], 90 [km], 95 [km], 99 [km], and 100 [km] from the point at which the excitation light is applied, respectively.

A predetermined scattered light power is determined as a reference point Ath with application of a predetermined excitation light power Pjdg at a loss point between 0 [km] and 90 [km]. Then the excitation light power is raised at a fixed rate

from 0. Then, in case where the scattered light
power ASS does not reach the reference point Ath yet
even when the excitation light power reaches Pjdg,
it is determined that a loss point occurs. In this

5   case, the control circuit 44 breaks the excitation
light and generates an alarm. On the other hand, in
case where the scattered light power ASS has already
reached the reference point Ath when the excitation
light power reaches Pjdg, it is determined that no

10   loss point occurs. In this case, the control
circuit 44 raises the excitation light power until
the signal light power reaches a target value.

FIG. 13 shows a block diagram of a
distributed Raman amplifier according to the third

15   embodiment of the present invention applying the
above-described control scheme. The same reference
numeral is given to the same portion as that in FIG.
5. In FIG. 13, through an optical fiber 30 which is
an optical transmission path pass, a signal light

20   for example with the wavelength of 1.55 μm is
transmitted. This signal light is applied to a band
separation optical coupler 32. An excitation light
with the wavelength of 1.45 μm is supplied to the
band separation optical coupler 32 through an

25   optical coupler 36 from an excitation light source
34, and is applied in a direction opposite to the
transmission direction of the signal light to the
optical fiber 30 with the band separation optical
coupler 32.

30   Thereby, the signal light is amplified by
using the optical fiber 30 as an amplifying medium.
The signal light thus having undergone the optical
amplification with the supply of the excitation
light is sent out to a subsequent optical fiber

35   through a band separation optical coupler 38 and an
optical coupler 40.

In the optical coupler 36, the excitation

light supplied from the excitation light source 34
is separated. The power of the excitation light is
monitored by an excitation light monitor 42, and the
thus-obtained monitoring signal is supplied to a
5   control circuit 54. The power of the scattered
light separated with the band separation optical
coupler 38 is also monitored by a scattered light
monitor 48, and the thus-obtained monitoring signal
of the scattered light power is also supplied to the
10   control circuit 54. The power of the signal light
separated with the optical coupler 40 is also
monitored by a signal light monitor 50, and the
thus-obtained monitoring signal of the signal light
power is supplied to the control circuit 54.
15   The control circuit 54 adjusts the
excitation light power which the excitation light
source 34 originally outputs, according to the thus-
obtained respective monitoring signals of the
excitation light power, scattered light power, and
20   signal light power. When operating the device (DRA),
the control circuit 54 raises the excitation light
power at a fixed rate from 0, and, when the
excitation light power P reaches the predetermined
determination value Pjdg but the scattered light
25   power ASS has not arrived at the reference point Ath
yet, the control circuit 54 determines that a loss
point exists, and breaks the excitation light, with,
for example, generating an alarm to a host apparatus,
as mentioned above.
30   In case the scattered light power has
already reached the reference point Ath when the
excitation light power reaches Pjdg, the control
circuit 54 determines that a loss point does not
exist in the optical transmission path. Then, the
35   control circuit 54 raises the excitation light power
up to the target value Pth, and, after that, the
control circuit 54 maintains the excitation light

power P as mentioned above.

Thus, by monitoring the scattered light, and controlling the output of excitation light power accordingly, it becomes possible to prevent burning

5   out at a loss point. Accordingly, at a time of starting up in an actual field, connector joints having harmful loss points, i.e., loss points having large losses, are automatically detected, and, based on the thus-obtained detection result, a manner of

10   controlling the excitation light power actually applied is determined before the plant starts commercial operation. Accordingly, it is possible to simplify starting up operation and also to achieve safe commercial operation.

15   FIG. 14 shows a block diagram of a distributed Raman amplifier according to a fourth embodiment of the present invention. The same reference numeral is given to the same portion as that in FIG. 13. Different from FIG. 13, the

20   configuration shown in FIG. 14 includes a band separation optical coupler 39 provided instead of the band separation optical coupler 38. In FIG. 14, through an optical fiber 30 which is an optical transmission path pass, a signal light with the

25   wavelength of 1.55 μm for example is transmitted. This signal light is applied to a band separation optical coupler 32. An excitation light with the wavelength of 1.45 μm is supplied also to the band separation optical coupler 32 through an optical

30   coupler 36 from an excitation light source 34, and is applied in a direction opposite to the transmission direction of the signal light to the optical fiber 30 with the band separation optical coupler 32.

35   Thereby, the signal light is amplified with a use of the optical fiber 30 as an amplifying medium. The signal light thus having undergone the

optical amplification with the supply of the excitation light is sent out to a subsequent optical fiber through an optical coupler 40.

In the optical coupler 36, the excitation
5 light supplied from the excitation light source 34 is separated. Then the power of the excitation light monitored by an excitation light monitor 42, and the thus-obtained monitoring signal is supplied to a control circuit 54. The scattered light and
10 signal light together separated with the optical coupler 40 are then separated into the scattered light and the signal light by the band separation optical coupler 39, and then, the power of the scattered light is monitored by a scattered light
15 monitor 48, the thus-obtained monitoring signal of the scattered light power being then supplied to the control circuit 54. On the other hand, the power of the signal light is monitored by a signal light monitor 50, and the thus-obtained monitoring signal
20 of the signal light power is supplied to the control circuit 54.

The control circuit 54 adjusts the excitation light power which the excitation light source 34 originally outputs, according to the thus-
25 obtained respective monitoring signals of the excitation light power, scattered light power, and signal light power. Operation of the control circuit 54 is the same as that of the third embodiment described above, and the duplicated
30 description is omitted.

The above-mentioned scattered light monitor 48 acts as a scattered-light monitoring part, the excitation light monitor 42 acts as an excitation-light monitoring part, the reflected
35 light monitor 46 acts as a reflected-light monitoring part, the control circuit 44/54 acts as a determining part, the control circuit 44/54 also

acts as a breaking part, the band separation optical coupler 38 acts as a first band separation optical coupler, and the band separation optical coupler 39 acts as a second band separation optical coupler.

5   The present invention is not limited to the above-described embodiments, and variations and modifications may be made without departing from the claimed scope of the present invention.

        The present application is based on
10 Japanese priority application No. 2002-322574, filed on November 6, 2002, the entire contents of which are hereby incorporated by reference.